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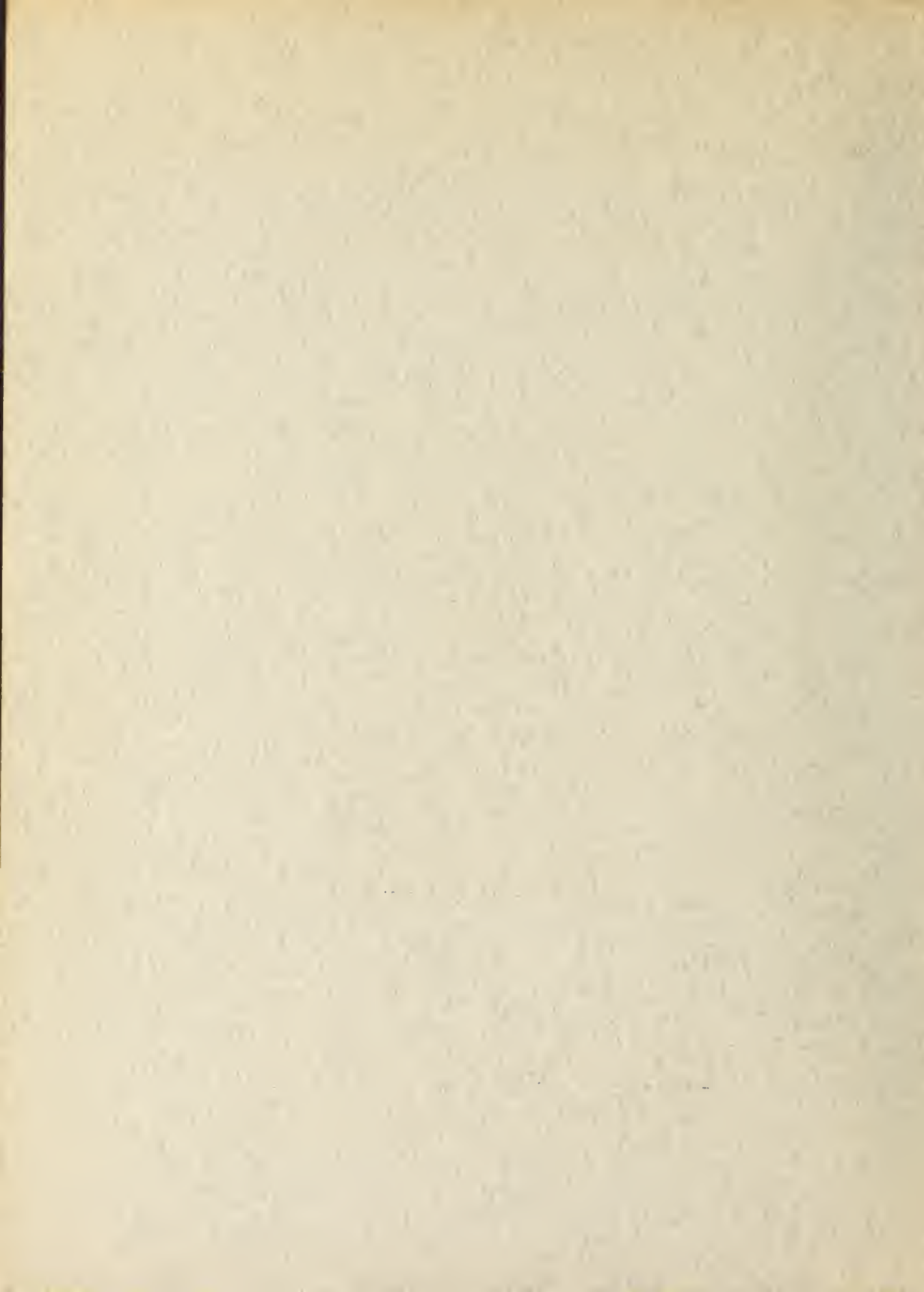
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FOREST SERVICE
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Madison, Wisconsin**

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EFFECT ON PAPREG OF SIX WATER-ALCOHOL RATIOS

USED AS DILUENTS OF IMPREGNATING RESINS¹

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Preliminary experiments, previously reported by the Forest Products Laboratory,² indicated that some properties of papreg³ were appreciably affected by impregnating the base paper with resin varnishes which had been diluted with a mixture of water and alcohol in place of alcohol alone. The water resistance was found to be considerably improved, but the Izod impact values were somewhat lowered. This report presents more conclusive data on the subject.

Test Material

The base paper (M.R. 2047) used in these experiments was made on the Forest Products Laboratory experimental paper machine from a commercial Mitscherlich spruce sulfite pulp especially developed from Laboratory specifications for this purpose. The paper was impregnated with six water-alcohol (ethyl) solutions of phenol-formaldehyde resin, Bakelite No. BV-16303. The term "alcohol" used throughout this report refers to the commercial 95 percent grade. In each solution the resin solids content was 40 percent by weight, but the proportion of water in the water-alcohol diluent was varied from 0 to 50 percent by volume in 10 percent steps. The resin content of the paper was held at 36 ± 0.3 percent and the volatile content at 4.5 ± 0.1 percent throughout the impregnation series. All plastic panels were parallel

¹-This mimeograph is one of a series of progress reports issued by the Forest Products Laboratory to further the nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

²-High-strength Laminated Paper Plastics for Aircraft, Mimeo. No. 1395, Revised April 1943 (restricted).

³-The name "papreg," identifying the experimental high-strength laminated paper plastic developed by the Forest Products Laboratory, has been sent to the U. S. Patent Office for registration.

laminated at 250 pounds per square inch for 12 minutes at 325° F. Specimens were prepared, conditioned, and tested for tension, compression, bending, Izod impact, total water absorption, and specific gravity determined, according to procedures set forth in "Proposed Federal Specifications for Organic Plastics; General Specifications (Methods of Physical Tests)" July 7, 1942.

In addition to the standard total water absorption test, the face water absorption of the papreg was determined by a special test method⁴ developed at the Laboratory and as yet unpublished. Since the edges of papreg as used in many applications, such as wing skins or fuselage surfaces, will be protected or sealed from moisture, it is believed that this type of test for water absorption is of particular value.

Discussion of Results

Water Absorption

The decrease in the water absorption of papreg, which occurs with an increase in the water to alcohol ratio of the resin diluent, over the range studied, is shown for both test methods in table 1 and figure 1. The total water absorption of papreg was reduced from 4.7 percent when alcohol alone was used as the diluent to 1.4 percent when the resin was diluted with a half-and-half mixture of water and alcohol. The face water absorption was reduced from 6.3 mg. per square cm. to 2.6 mg. per square cm. by the same procedure. This effect may be attributed to a greater penetration of resin into the fiber wall when a higher proportion of water is present. Unpublished Laboratory data on wood and paper treated with water-soluble resin corroborates this explanation and indicates that such treatment actually reduces the equilibrium moisture content and thus produces a more permanent water-resistant material in addition to retarding the rate of water absorption as measured by the standard test method.

The appearance of the plastic after exposure to water in the face absorption test is a visual measure of the effect of the various water-alcohol diluent mixtures of the impregnating resin. This is illustrated in figure 2.

⁴Face water absorption test.--A sample, 2-1/2 inches square, is conditioned 24 hours at 50° C. and its weight determined. A 2-inch diameter brass cap with rubber washer is then clamped on the specimen. The cap is filled with distilled water through a small hole, the hole stopped, and the assembly placed in a desiccator for 24 hours at room temperature. The specimen is then removed from the cap, wiped dry, and weighed. The face water absorption value is expressed as milligrams per square centimeter absorbed in 24 hours.

Specific Gravity

As the water to alcohol ratio was increased, the specific gravity of the resulting papreg decreased slightly. This effect should be taken into consideration for strict comparison of the papreg strength data, but for practical purposes the strength data are directly comparable.

Ultimate Tensile Strength

The ultimate tensile strength of the plastic was affected but little by an increase of the water-alcohol ratio of the resin diluent for impregnation. Compared to the strength obtained from papreg made with a resin diluted with alcohol alone, a decrease in tensile strength of less than 7 percent occurred when a half-and-half water-alcohol mixture was used.

Edgewise Compressive Strength

The maximum edgewise compressive strength of the papreg was increased from about 23,000 pounds per square inch when alcohol alone was used as the resin diluent, to 27,200 pounds per square inch when a 50 percent mixture of water and alcohol was used. The rate of increase of the edgewise compressive strength was greatest in the range where the proportion of water to alcohol was from 30 to 40 percent. This is shown in figure 3.

Modulus of Rupture

The modulus of rupture of papreg was not greatly affected by changes in the solvent used in the resin impregnating mixture, although there was a trend toward lower bending values as the proportion of water was increased.

Moduli of Elasticity

The changes in moduli of elasticity in compression, bending, and tension were so small, with an increase in the amount of water added to the alcohol in the impregnating mixture, that they can be interpreted only as trends.

Izod Impact

A marked loss in the Izod impact resistance of the papreg occurred with an increase in the proportion of water to alcohol. Increasing the water-alcohol ratio from 0 percent water to 50 percent water resulted in a decrease of the impact resistance of flatwise notched specimens from 5.5 to 3.3 foot pounds per inch of notch (table 1 and fig. 4). The impact resistance of edgewise notched specimens decreased from 0.79 to 0.61 foot pounds per inch of notch.

Conclusions

Results obtained under the conditions described show that certain properties of papreg were definitely affected by the use of various water-alcohol ratios in the mixtures used as a resin diluent for paper impregnation. The following effects were observed when there was an increase in the ratio of water to alcohol from 0 percent water to 50 percent water:

The water resistance as measured by both total and face water absorption methods was greatly improved, and the maximum edgewise compressive strength was increased nearly 20 percent. The loss in flatwise Izod impact resistance was 40 percent and the loss in edgewise impact resistance was nearly 23 percent.

The specific gravity decreased only slightly and the ultimate tensile strength, modulus of rupture, and moduli of elasticity in tension, bending, and compression were not appreciably affected.

Table 1.--Properties of papreg made from paper impregnated with resin diluted with various water-alcohol mixtures¹.

Resin diluent:		Properties of papreg											
:	:	Tension	Edge compression:	Static bending :	Izod impact :	Water absorption							
95	:	:	:	:	:	:							
Plastic percent:	:	:	:	:	:	:							
number	:	Ultimate:	Modulus :	Maximum:	Modulus :	Notched :	Specific :	Total :	Face				
alcohol:	:	of elas-	of elas-	of elas-	of elas-	edgewise:	gravity :	24 hrs.	24 hrs.				
:	:	ticity :	ticity :	ticity :	ticity :	rupture:	:	:	:				
:	:	:	:	:	:	:	:	:	:				
Percent	:	Lb. per	1000 lb.	Lb. per	1000 lb.	Ft. lb. per	inch of notch	Percent	Mg. per				
by volume	:	sq. in.	per sq.	sq. in.	per sq.	inch of notch	sq. cm.	:	:				
:	:	:	:	:	:	:	:	:	:				
2047-3	100	41,760	3,409	23,080	3,274	38,170	3,066	0.79	5.5	1.410	4.7	6.3	
2047-4	90	41,840	3,408	23,280	3,002	37,270	3,123	.76	4.9	1.408	3.8	4.2	
2047-5	80	42,037	3,452	23,570	3,140	38,480	3,176	.74	4.9	1.409	3.1	4.0	
2047-6	70	41,793	3,462	24,740	3,102	37,160	3,242	.70	4.2	1.406	2.1	3.1	
2047-7	60	41,550	3,528	26,400	3,250	36,750	3,242	.64	3.8	1.399	1.7	2.7	
2047-8	50	39,117	3,519	27,200	3,184	35,720	3,256	.61	3.3	1.390	1.4	2.6	

¹Mitscherlich sulfite base paper, impregnated with 36 percent of phenol-formaldehyde resin Bakelite BV-16303, parallel laminated at 250 pounds per square inch at 325° F. for 12 minutes. Strength tests were made parallel to the fiber direction (grain). Except as otherwise noted, all tests were made in accordance with "Proposed Federal Specifications for Organic Plastics; General Specifications (Methods of Physical Tests)" July 7, 1942.

²Face water absorption test, Forest Products Laboratory method of May, 1943.

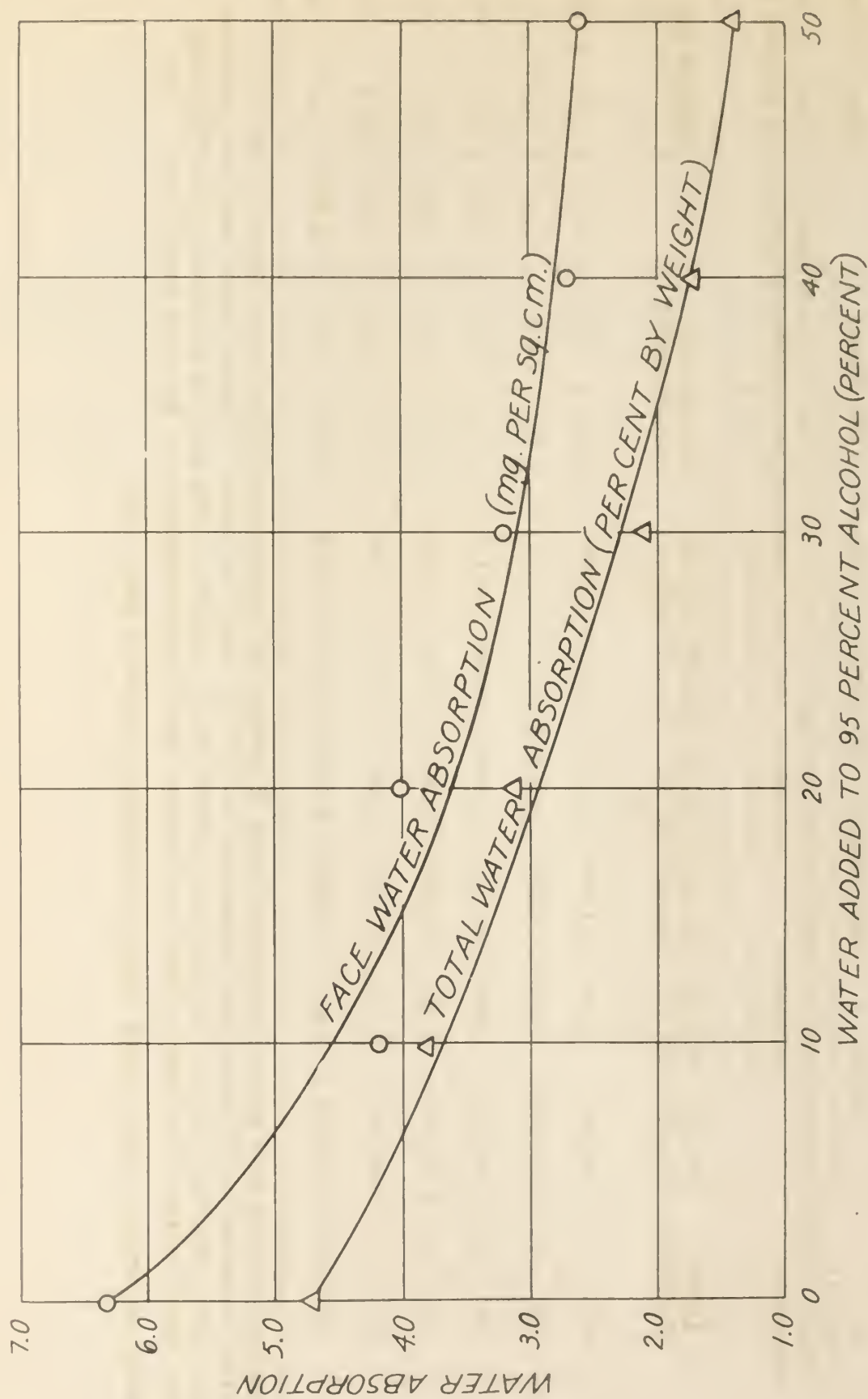
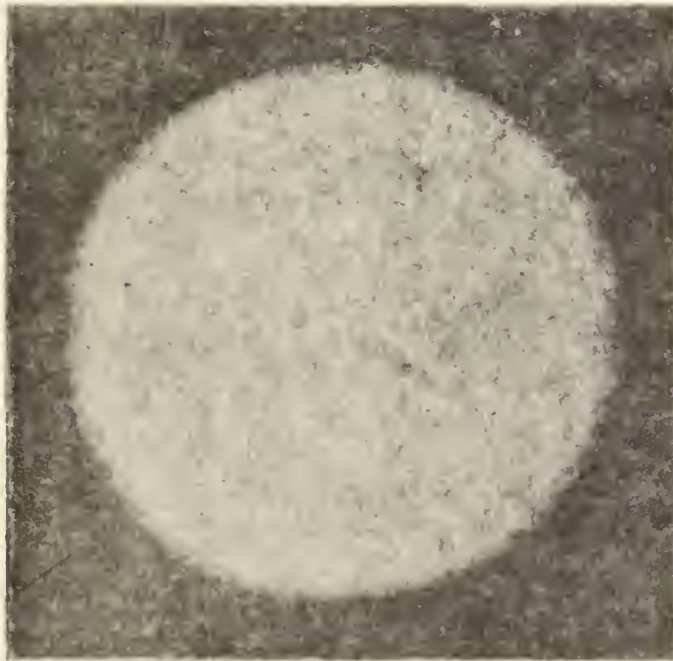
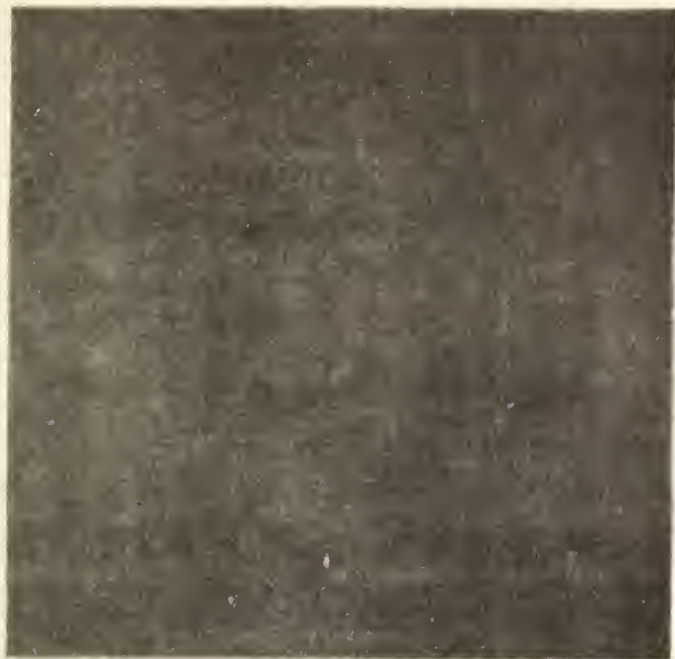


Figure 1.--Effect of water-alcohol mixtures in the resin solution on the water absorption of papreg.



A



B

Figure 2.--Appearance, after exposure to water for 24 hours, of the surface of papreg: A, water in water-alcohol diluent of resin 0 percent to 20 percent, water absorbed by papreg 6.3 to 4.0 milligrams per square centimeter; B, water in water-alcohol diluent of resin 30 percent to 50 percent, water absorbed by papreg 3.1 to 2.6 milligrams per square centimeter.

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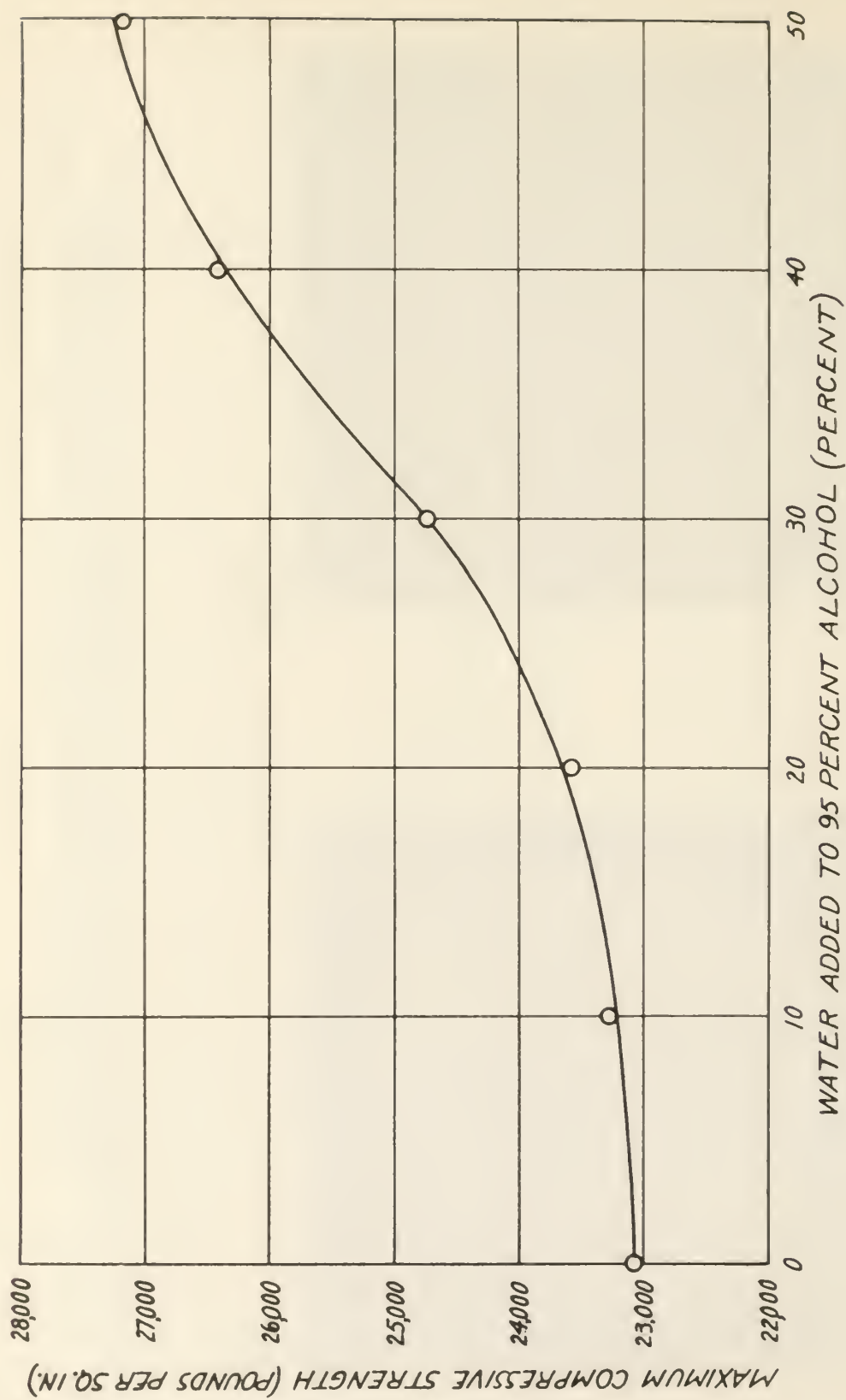


Figure 3.--Effect of water-alcohol mixtures in the resin solution on the maximum edgewise compressive strength of papreg.

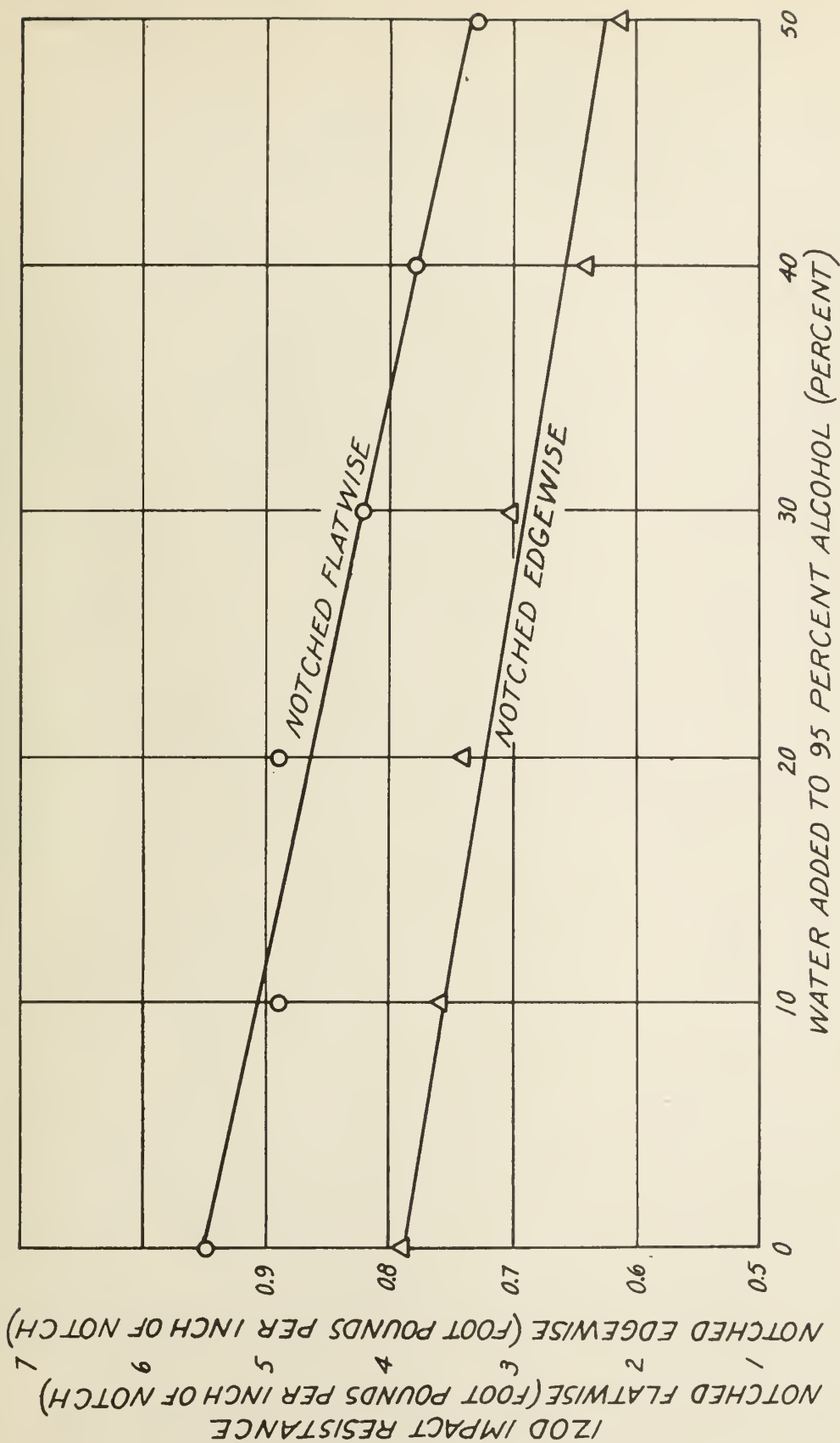
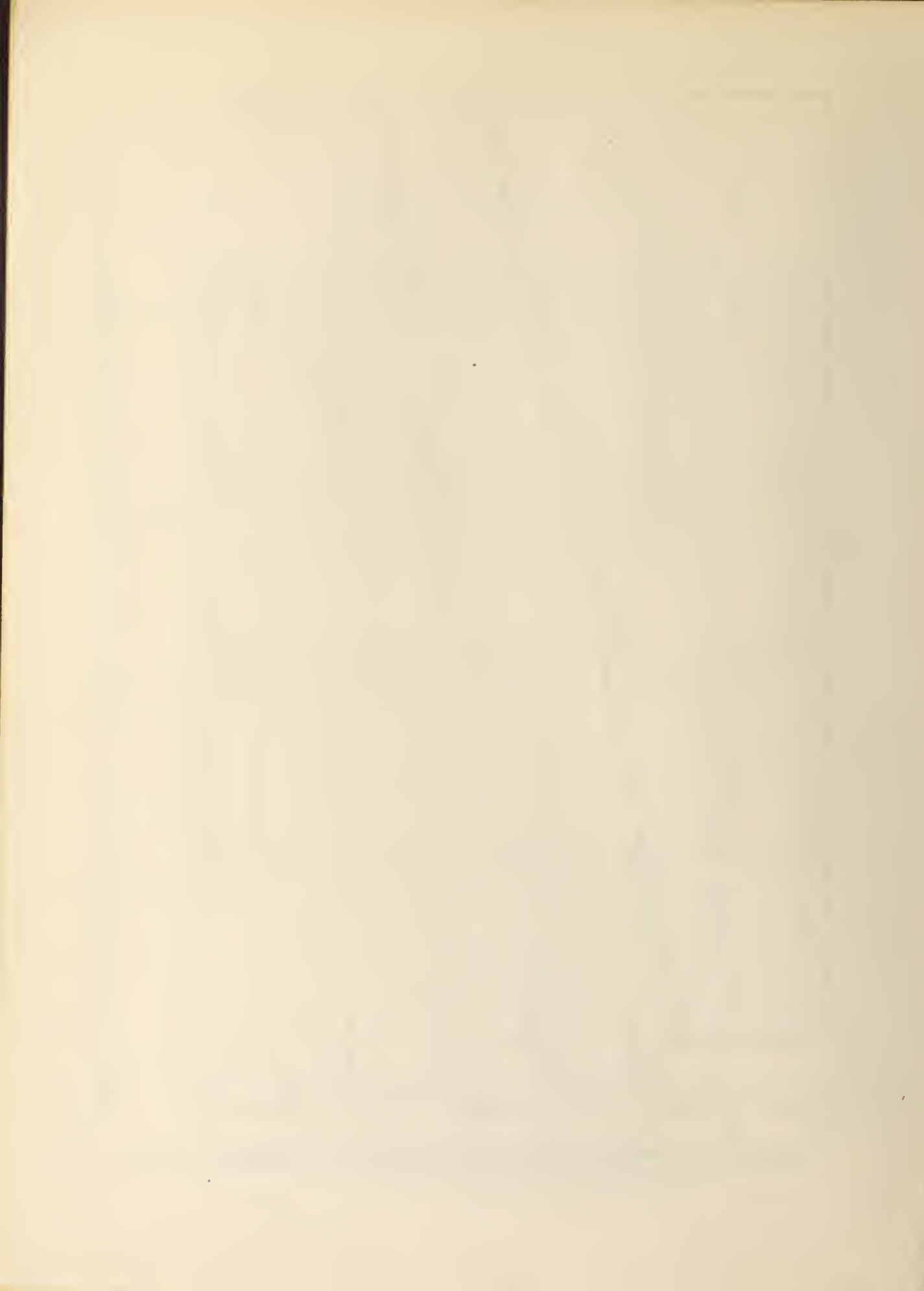


Figure 4.--Effect of water-alcohol mixtures in the resin solution on the Izod impact resistance of papreg.



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